7.0 REMEDY SELECTION CONSIDERATIONS

> No two sites are identical and therefore the risk-management strategy will vary from site to site... The strategy selected should be one that actually reduces overall risk, not merely transfers the risk to another site or another affected population. The decision process necessary to arrive at an optimal management strategy is complex and likely to involve numerous site-specific considerations...
>
> Management decisions must be made, even when information is imperfect. There are uncertainties associated with every decision that need to be weighed, evaluated, and communicated to affected parties. Imperfect knowledge must not become an excuse for not making a decision.

In these two statements from the National Research Council's (NRC's) report *A Risk Management Strategy for PCB-Contaminated Sediments* (NRC 2001), the NRC identifies some of the key challenges faced by many project managers at the remedy selection stage. The program goal of the Superfund remedy selection process is to select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste [Title 40 Code of Federal Regulations (40 CFR) §300.430(a)(1)(i)]. Superfund remedies must also be cost-effective and use permanent solutions to the maximum extent practicable [Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) §121(b)]. The best route to meeting these and other requirements, as well as the best route to overall risk reduction, depends on a large number of site-specific considerations, some of which may be subject to significant uncertainty. Although final decision making in the face of imperfect knowledge may be necessary, it may be appropriate to postpone a final decision if there is significant doubt about the proposed action's ability to reduce site risks substantially in light of the potential magnitude of costs associated with addressing certain sediment sites. Postponing a final decision may provide an opportunity to conduct additional investigation or pilot studies, and would not necessarily preclude carrying out appropriate interim response actions at the same time.

7.1 RISK MANAGEMENT DECISION MAKING

Consistent with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), each of the risk management principles in the U.S. Environmental Protection Agency's (EPA's) *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (U.S. EPA 2002a; see Appendix A), is important to consider for achieving a successful sediment cleanup. Several of the principles apply more directly to the remedy selection stage, especially Principle 7, Select Site-Specific, Project-Specific, and Sediment-Specific Risk Management Approaches that will Achieve Risk-based Goals. Any decision regarding the specific choice of a remedy for a contaminated sediment site should be based on a careful consideration of the advantages and limitations of available approaches and a balancing of tradeoffs among alternatives.

A risk management process should be used to select a remedy designed to reduce the key human and ecological risks effectively. Another important risk management function generally is to compare and contrast the costs and benefits of various remedies. As noted in EPA's *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessment* (U.S. EPA 1997d), risk assessments should provide a basis for comparing, ranking, and prioritizing risks. The results can also be used in cost-effectiveness analyses that offer additional interpretation of the effects of alternative management options.

In addition, risk management goals should be developed that can be evaluated within a realistic time period, acknowledging that it may not be practical to achieve all goals in the short term. Risk management of contaminated sediment should comprehensively evaluate the broad range of risks posed by contaminated sediment and associated remedial actions, while recognizing that some risks may be reduced in a shorter time frame than others.

EPA's *Rules of Thumb for Superfund Remedy Selection* (U.S. EPA 1997c, also referred to as the "Rule of Thumb Guidance") is a helpful guidance for project managers to review when making risk-management decisions and selecting remedies at sediment sites. The Rules of Thumb Guidance describes key principles and expectations, interspersed with "best practices" based on program experience and policies. In addition, this guidance discusses how remedy selection may also be applicable to the Resource Conservation and Recovery Act (RCRA) Corrective Action Program. For more information on the two cleanup programs, the project manager should refer to Office of Solid Waste and Emergency Response (OSWER) Directive 9200.0-25, *Coordination Between RCRA Corrective Action and Closure and CERCLA Site Activities* (U.S. EPA 1996f).

Decisions regarding risk management and remedy selection should also consider pertinent recommendations from stakeholders, which frequently include the local community, local government, states, Indian tribes, and responsible parties. Remediation may significantly impact day-to-day activities of residents and recreation-seekers, and operations of commercial establishments near the water body for extended periods. Stakeholders should be involved when designing and scheduling remedial operations, not just during the remedy selection process. Documenting and communicating how and why remedy decisions are made are very important tasks at sediment sites. For guidance on documenting remedy decisions under CERCLA, project managers should refer to EPA's *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and other Remedy Selection Documents*, also referred to as the "ROD Guidance" (U.S. EPA 1999a).

7.2 NCP REMEDY SELECTION FRAMEWORK

In the NCP, EPA provides a series of expectations (see Highlight 7-1) to reflect the principal requirements under CERCLA §121 and to help focus the remedial investigation/feasibility study (RI/FS) on appropriate cleanup options. EPA developed nine criteria for evaluating remedial alternatives to ensure that all important considerations are factored into remedy selection decisions. Chapter 3, Section 3.2 outlines the NCP's nine remedy selection criteria. These criteria are derived from the statutory requirements under CERCLA §121, as well as technical and policy considerations that have proven to be important for selecting among the remedial alternatives. In general, the nine criteria analysis comprises the following two steps: 1) an evaluation of all alternatives with respect to each criterion; and 2) a comparison among the alternatives to determine the relative performance of the alternatives and identify major trade-offs among them (i.e., relative advantages and limitations). Generally this comparison is made on a qualitative basis, although some have attempted a quantitative analysis (e.g., Linkov et al. 2004). Ultimately, the remedy selected must be protective of human health and the environment, attain (or waive) applicable or relevant and appropriate requirements (ARARs), be cost effective, use permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable, and satisfy a preference for treatment or provide an explanation as to why this preference was not met.

Consistent with CERCLA and the NCP, each remedial action selected should be cost-effective. The NCP provides several threshold criteria that should be satisfied (40 CFR §300.430(f)(ii)(D)). Cost-effectiveness is generally determined by evaluating three of the five balancing criteria: 1) long-term effectiveness and permanence; 2) reduction of toxicity, mobility, or volume of hazardous substances through treatment; and 3) short-term effectiveness. A remedy typically is considered cost effective when its cost is proportional to its overall effectiveness. As described in the preamble to the NCP, more than one alternative may be considered cost-effective (55 *Federal Register* (*FR*) 8728, March 8, 1990). The relationship between overall effectiveness and cost should be examined across all alternatives to identify which options can best afford effectiveness proportional to their cost. The evaluation of an alternative's cost effectiveness is usually concerned with the reasonableness of the relationship between the effectiveness afforded by each alternative and its costs when compared to other available options (U.S. EPA 1999a).

For some complex sediment sites, there may be a high degree of uncertainty about the predicted effectiveness of various remedial alternatives. Where this is the case, it is especially important to identify and factor that uncertainty into site decisions. Project managers are encouraged to consider a range of probable effectiveness scenarios that includes both optimistic and non-ideal site conditions and remedy performance.

The NCP lists six "expectations" that EPA generally considers in developing appropriate remedial alternatives at Superfund sites (40 CFR §300.430(a)(1)(iii)). Highlight 7-1 discusses how the six expectations may be relevant for sites with contaminated sediment. Generally, the expectations are addressed by seeking the best balance of trade-offs among the alternatives evaluated.

7.3 CONSIDERING REMEDIES

If the baseline risk assessment determines that contaminated sediment presents an unacceptable risk to human health or the environment, remedial alternatives should be developed to reduce those risks to acceptable levels. As discussed in Chapter 3, Section 3.1, Developing Remedial Alternatives for Sediment, due to the limited number of approaches available for contaminated sediment, generally, project managers should evaluate each of the three major approaches monitored natural recovery (MNR), in-situ capping, and removal through dredging or excavation at every sediment site. Depending on site-specific conditions, contaminant characteristics, and/or health or environmental risks at issue, certain methods or combinations of methods may prove more promising than others. Each site and the various sediment areas within it presents a unique combination of circumstances that should be considered carefully in selecting a comprehensive site-wide cleanup strategy. At large or complex sediment sites, the remedy decision frequently involves choices between areas of the site and how they are best suited to particular cleanup methods rather than a simple one-size-fits-all choice between approaches for the entire site.

Project managers should keep in mind that deeper contaminated sediment that is not currently bioavailable or bioaccessible, and that analyses have shown to be stable to a reasonable degree, do not necessarily contribute to site risks. In evaluating whether to leave buried contaminated sediment in place, project managers should include an analysis of several factors, including the depth to which significant

Highlight 7-1: NCP Remedy Expectations and Their Potential Application to Contaminated Sediment
EPA expects to use treatment to address the principal threats posed by a site, wherever practicable: • In general, wastes, including contaminated sediment, may be considered a principal threat where toxicity and mobility combine to pose a potential human health risk of 10^{-3} or greater for carcinogens (U.S. EPA 1991d). For these areas, project managers should evaluate an alternative that includes treatment. However, the practicability of treatment, and whether a treatment alternative should be selected, should be evaluated against the NCP's nine remedy selection criteria. Based on available technology, treatment is not considered practicable at most sediment sites
EPA expects to use engineering controls, such as containment, for waste that poses a relatively low long-term threat or where treatment is impracticable: • Containment options for sediment generally focus on in-situ capping. A project manager should evaluate in-situ capping for every sediment site that includes low-level threat waste. Where a containment alternative is clearly not appropriate for a detailed evaluation, project managers should evaluate ex-situ containment (i.e., disposal without treatment). It should be recognized that in-situ containment can also be effective for principal threat wastes, where that approach represents the best balance of the NCP nine remedy selection criteria
EPA expects to use a combination of methods, as appropriate, to achieve protection of human health and the environment: • Large or complex contaminated sediment sites or operable units frequently require development of alternatives that combine various approaches for different parts of the site. For a broader discussion on this topic, refer to Chapter 3, Section 3.1.1, Alternatives that Combine Approaches
EPA expects to use institutional controls, such as water use and deed restrictions, to supplement engineering controls as appropriate for short- and long-term management to prevent or limit exposure to hazardous substances, pollutants, or contaminants: • Institutional controls such as fish consumption advisories, fishing bans, ship draft/anchoring/wake controls, or structural maintenance requirements (e.g., dam or breakwater maintenance) are frequently a part of sediment alternatives, especially where contaminated sediment is left in place, or where remedial goals in fish tissue cannot be met for some time. See Chapter 3, Section 3.6, Institutional Controls, for additional discussion
EPA expects to consider using innovative technology when such technology offers the potential for comparable or superior treatment performance or implementability, fewer or lesser adverse impacts than other available approaches, or lower costs for similar levels of performance than demonstrated technologies: • Innovative technologies are technologies whose limited number of applications may result in less cost and performance data, frequently due to limited field application. Additional cost and performance data may be needed for many sediment remedies, and field demonstrations of new techniques and approaches may be especially needed, including both innovative in-situ and ex-situ technologies. Although most innovations for sediment remedies are currently in the research phase, as they become available, project managers should consider using them
EPA expects to return reusable ground waters to their beneficial uses wherever practicable, within a time frame that is reasonable given the circumstances for the site. When restoration of ground water to beneficial uses is not practicable, EPA expects to prevent further migration of the plume, prevent exposure to the contaminated ground water, and evaluate further risk reduction: • Ground water may be a continuing source of sediment and surface water contamination. Where this is the case, ground water migration prevention may be very important to a successful sediment cleanup and to protect benthic biota. Ground water restoration may also be needed to return the ground water to a beneficial use

populations of organisms burrow, the potential for erosion due to natural or anthropogenic (man-made) forces, the potential for contaminant movement via ground water, and the effectiveness of any institutional controls (ICs) to limit sediment disturbance. In some cases, the most appropriate approach may be long-term monitoring, with contingency actions, if necessary.

To assist project managers in evaluating cleanup options, two summary highlights are presented below. Highlight 7-2 provides general site, sediment, and contaminant characteristics or conditions especially conducive to each of the three common sediment approaches. This highlight is intended as a general tool for project managers as they look more closely at particular approaches when most of these characteristics are present. Project managers should note that these characteristics are not requirements. It is important to remain flexible when evaluating sediment alternatives and when considering approaches that at first may not appear the most appropriate for a given environment. When an approach is selected for a site that has one or more site characteristics or conditions appearing problematic, additional engineering or ICs may be available to enhance the remedy. Some of these situations are discussed in the remedy-specific chapters (Chapters 4, 5, and 6).

Highlight 7-2: Some Site Characteristics and Conditions Especially Conducive to Particular Remedial Approaches for Contaminated Sediment

Characteristics	Monitored Natural Recovery	In-situ Capping	Dredging/Excavation
General Site Characteristics	Anticipated land uses or new structures are not incompatible with natural recovery Natural recovery processes have a reasonable degree of certainty to continue at rates that will contain, destroy, or reduce the bioavailability or toxicity of contaminants within an acceptable time frame	Suitable types and quantities of cap material are available Anticipated infrastructure needs (e.g., piers, pilings, buried cables) are compatible with cap Water depth is adequate to accommodate cap with anticipated uses (e.g., navigation, flood control) Incidence of cap-disrupting human behavior, such as large boat anchoring, is low or controllable	Suitable disposal sites are available Suitable area is available for staging and handling of dredged material Existing shoreline areas and infrastructure (e.g., piers, pilings, buried cables) can accommodate dredging or excavation needs Navigational dredging is scheduled or planned
Human and Ecological Environment	Expected human exposure is low and/or reasonably controlled by ICs Site includes sensitive, unique environments that could be irreversibly damaged by capping or dredging	Expected human exposure is substantial and not well-controlled by ICs Long-term risk reduction outweighs habitat disruption, and/or habitat improvements are provided by the cap	Expected human exposure is substantial and not well-controlled by ICs Long-term risk reduction of sediment removal outweighs sediment disturbance and habitat disruption

Characteristics	Monitored Natural Recovery	In-situ Capping	Dredging/Excavation
Hydrodynamic Conditions	Deposition of sediment is occurring in the areas of contamination Hydrodynamic conditions (e.g., floods, ice scour) are not likely to compromise natural recovery	Hydrodynamic conditions (e.g., floods, ice scour) are not likely to compromise cap or can be accommodated in design Rates of ground water flow in cap area are low and not likely to create unacceptable contaminant releases	Water diversion is practical, or current velocity is low or can be minimized to reduce resuspension and downstream transport during dredging
Sediment Characteristics	Sediment is resistant to resuspension (e.g., cohesive or well-armored sediment)	Sediment has sufficient strength to support cap (e.g., has high density/low water content)	Contaminated sediment is underlain by clean sediment (so that over-dredging is feasible) Sediment contains low incidence of debris (e.g., logs, boulders, scrap material) or is amenable to effective debris removal prior to dredging or excavation
Contaminant Characteristics	Contaminant concentrations in biota and in the biologically active zone of sediment are moving towards risk-based goals Contaminants readily biodegrade or transform to lower toxicity forms Contaminant concentrations are low and cover diffuse areas Contaminants have low ability to bioaccumulate	Contaminants have low rates of flux through cap Contamination covers contiguous areas (e.g., to simplify capping)	Higher contaminant concentrations cover discrete areas Contaminants are highly correlated with sediment grain size (i.e., to facilitate separation and minimize disposal costs)

Highlight 7-3 may assist project managers in evaluating cleanup options. For convenience, these comparisons are organized around the NCP's nine remedy selection criteria. This highlight is intended only to identify some of the general differences between these three remedy types, not as an example of an actual comparative alternatives analysis for a site. An actual site alternatives analysis would typically include more complex alternatives and many site-specific details, as described in the ROD Guidance (U.S. EPA 1999a) and EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (U.S. EPA 1988a, commonly referred to as the "RI/FS Guidance"). The example criterion components column used in Highlight 7-3 below are adapted from the RI/FS Guidance and are intended only as examples of some of the components that may be considered when evaluating each remedy selection criterion.

Highlight 7-3: Examples of Some Key Differences Between Remedial Approaches for Contaminated Sediment

NCP Remedy Selection Criteria	Example Criterion Components	Monitored Natural Recovery	In-Situ Capping	Dredging/Excavation
Overall Protective-ness		Generally relies upon natural processes for protection May provide low level of short-term protection, but may provide potentially acceptable long-term protection	Generally, relies upon adequate cap placement and maintenance for protection May provide moderate to high level of protection, depending upon areal extent, design of cap, and long-term maintenance	Generally, relies upon effective removal and low residual levels for protection May provide moderate to high level of protection, depending on residual, or where remedy is combined with backfilling, capping, or MNR
Compliance with Applicable or Relevant and Appropriate Require-ments (ARARs)		Generally, only chemical-specific ARARs apply (these would also apply to other approaches)	Generally, the Clean Water Act (CWA) §404 (regulates discharge of dredged or fill materials into waters of the U.S.) and the Rivers and Harbors Act (prohibits obstruction or alteration of a navigable waterway) are ARARs See Chapter 3, Section 3.3, for additional examples of ARARs	Generally, CWA §404 and the Rivers and Harbors Act are ARARs. Generally, treatment facilities and in-water disposal sites should meet substantive requirements of the CWA §§404 and 401 for discharge of effluents into waters of the U.S. Generally, state solid hazardous waste rules and RCRA is an ARAR for disposal in solid or hazardous waste landfills See Chapter 3, Section 3.3, for additional examples of ARARs
Long-Term Effective-ness and Permanence	**Magnitude of Risk Reduction and Residual Risks**	May provide low to high level of risk reduction and residual risk, depending on processes being relied upon and site-specific characteristics that might enhance or prevent long-term isolation or destruction of contaminants	May provide moderate to high level of risk reduction and low to moderate residual risk, depending on cap design, placement, construction, and maintenance to address site characteristics that might otherwise prevent long-term isolation of contaminants	May provide moderate to high level of risk reduction and low to moderate residual risk, depending on effectiveness of dredging and use of backfill material May provide low (upland) to moderate (in-water) residual risk for sediments and treatment residuals contained at controlled disposal sites

NCP Remedy Selection Criteria	Example Criterion Components	Monitored Natural Recovery	In-Situ Capping	Dredging/Excavation
Long-Term Effective-ness and Permanence (cont.)	**Adequacy and Reliability of Controls for Residual Risk**	May provide low control, but potentially acceptable, depending on processes being relied upon and site-specific conditions May provide moderate ability to control physical disturbance due to human activity via institutional controls; may provide little ability to control physical disturbance due to natural forces May provide no ability to control advection and diffusion of contaminants through overlying cleaner sediment, where this is of concern	May provide moderate to high control, depending on cap stability and contaminant migration through cap May provide low to moderate ability to control physical disturbance due to human and natural forces and to control effects of advective flow and diffusion through cap design and moderate ability to control disruption through institutional controls	May provide high control due to removal of contaminants, if residual contamination is below cleanup levels or addressed through backfilling, or capping May leave residual risks at upland disposal sites that are easily controlled; at in-water sites control can be more complex
	Need for Five-Year Reviews	Five-year reviews generally would be required for most sites due to waste left in place and possible continuing need for use restrictions	Five-year reviews generally would be required for most sites due to waste left in place and possible continuing need for use restrictions	Five-year review may be generally required until remedial action objectives are met Reviews generally required for on-site disposal facilities
Reduction of Toxicity, Mobility, and Volume (TMV) Through Treatment		No treatment is involved	Typically, no treatment is involved Research is ongoing concerning the combination of innovative in-situ treatment components within a cap	Sediment is treated in some cases if practical and cost-effective; stabilization is most common form Potential exists for beneficial reuse of dredged sediment Water treatment can reduce TMV of contaminants where significant quantities of toxics are removed from the water

NCP Remedy Selection Criteria	Example Criterion Components	Monitored Natural Recovery	In-Situ Capping	Dredging/Excavation
Short-Term Effective-ness	**Environ-mental Impacts During Remedy Implemen-tation**	There should be no additional impact to bottom-dwelling ecological community from the remedy itself, but impacts of contaminated sediment on environment continue until protection is achieved	May provide high impact to bottom habitat in area of cap. Cap design can facilitate recolonization in some cases May provide low potential for impacts from releases to the environment during cap placement and initial consolidation	May provide high impact to bottom habitat in dredged area. Backfill design can facilitate recolonization in some cases May provide moderate potential for impacts to biota from release during dredging; releases partially controllable by physical barriers and by selection and operation of dredging equipment
	Community and Worker Protection During Remedy Implementa-tion	There should be no additional health impacts to community from the remedy itself; any pre-existing impacts would continue until protection is achieved May provide moderate ability to control community impacts from fish/shellfish ingestion and, where applicable, direct contact with contaminated sediment, through consumption advisories and use restrictions There should be minimal impacts on workers and community from monitoring activities	There should be low potential for health impacts to community and workers from contaminant releases during cap placement. Engineering controls may minimize these releases; worker protection generally available Increased truck or rail traffic for transport of cap material may impact workers and the community Staging needs for cap placement may disrupt local community during placement	There should be low to moderate potential for health impacts to community and workers from contaminant release during dredging, staging, transport, and disposal. Engineering controls may minimize these releases; worker protection generally available Increased truck or rail traffic for transport of dredged material may impact workers and the community Dredged materials and water handling or treatment needs may disrupt local community during dredging

NCP Remedy Selection Criteria	Example Criterion Components	Monitored Natural Recovery	In-Situ Capping	Dredging/Excavation
Short-Term Effective-ness (cont.)	**Time Until Protection is Achieved**	Generally, longest time to achieve protection, depending on rates of natural processes and bioavailability of the contaminants Time to achieve protection is frequently highly uncertain	Generally, shortest time to achieve protection Complete biota recovery could take several years Generally, most certainty concerning time to achieve protection	Time to achieve protection varies depending on the size and complexity of the project Complete biota recovery could take several years Time frame generally more uncertain than for capping due to difficulty of predicting residual contamination
Implement-ability	**Technical Feasibility**	Generally, no construction is required Reliability can be uncertain in some environments due to uncertain rates of natural processes and uncertainties concerning sediment stability Where site-specific conditions allow, should be relatively easy to implement a different remedy if MNR is not effective Methods for monitoring sediment cleanup levels are relatively well established	Cap placement methods are generally well-established; ability to construct a cap depends on a number of factors including water depth and currents, slope and geotechnical stability of underlying materials, and stability of the cap itself during and after construction Reliability generally high, depending on site-specific conditions, and degree of monitoring and maintenance Relatively easy to repair cap in case of localized erosion or disruption, but can be difficult or costly to implement sediment removal if cap is not effective Methods for monitoring cap integrity and contaminant migration within cap are relatively well established	Dredging and excavation methods are generally well-established; technical feasibility of dredging depends on a number of factors including accessibility, extent of debris, and the ability to over-dredge Disposal in upland landfills is a well-established technique; in-water disposal methods are less well-established and may require greater monitoring; technical feasibility generally depends on distance to the disposal site, ease of dewatering, and slope and geotechnical stability of disposal site May be necessary to re-dredge, cap or implement MNR if dredging alone does not meet cleanup standards Monitoring methods for sediment cleanup levels and short-term releases from dredging are relatively well established

NCP Remedy Selection Criteria	Example Criterion Components	Monitored Natural Recovery	In-Situ Capping	Dredging/Excavation
Implement-ability (cont.)	**Administra-tive Feasibility**	State-regulated ICs, including fish consumption advisories where contaminants are bioaccumulative, may be needed for a longer period than for other remedies	Containment in public waters can require long-term coordination with state and local regulators due to potential need for long-term controls on waterway use Where contaminants are bioaccumulative, fish consumption advisories frequently needed for a period of years. Length of time generally depends on residual contamination outside of capped area	Dredging and excavation plan should be coordinated with other agencies to ensure compatibility with other waterway uses and habitat concerns during the removal operation Where contaminants are bioaccumulative, fish consumption advisories frequently needed for a period of years. Length of time generally depends on residual contamination within and outside of dredged area Disposal siting often requires extensive coordination with several government agencies and the public
	Availability of Services, Materials, Capacities, and Equipment	Monitoring and analytical services are generally readily available	Location and suitability of capping material source is critical and can be problematic if not available locally Specialized cap placement equipment may be needed in some environments, but are generally available Availability of suitable cap material staging areas is critical and can be problematic for some sites (e.g., some urban areas)	Environmental dredging and excavation equipment is generally available, although availability may be a problem for large projects. Specialized equipment may need to be constructed for special situations Availability of suitable dredged material staging, separation, and, where required, water treatment capacity is critical and can be problematic for some sites (e.g., some urban areas) Availability of a suitable disposal facility is critical and can be problematic for some sites (e.g., where local disposal is infeasible or high volumes are involved)

NCP Remedy Selection Criteria	Example Criterion Components	Monitored Natural Recovery	In-Situ Capping	Dredging/Excavation
Cost		Generally, no capital cost Long-term monitoring costs typically continue until cleanup levels and remedial action objectives are met. Length of long-term monitoring is generally dependent on assurance of sediment stability	Capital costs generally higher than MNR and lower than dredging/ excavation Long-term maintenance and monitoring costs generally higher than MNR and dredging/ excavation Long-term monitoring costs typically continue until cleanup levels and remedial action objectives are met. Length of long-term operation and maintenance (O&M) period dependent on time necessary to verify long-term stability of cap and lack of significant contaminant fluxes through cap	Capital costs generally higher than MNR or capping Long-term monitoring costs generally lower than MNR and capping Long-term monitoring costs typically continue until cleanup levels and remedial action objectives are met. Length of long-term O&M period dependent on extent of residual contamination and use of on-site disposal
State Acceptance and Community Acceptance		Commonly identified benefits include lack of disruption to local residents, lack of disruption to aquatic and terrestrial animal and plant life, and low cost	Commonly identified benefits include use of an active remedy with no disposal issues, generally moderate cost, and potentially faster biota recovery than MNR or dredging due to rapid placement of exposure barrier	Commonly identified benefits include removing contaminants from waterway, possible treatment of contaminants, faster biota recovery than MNR, increased/restored navigational depth, decreased flooding, and lack of use limitations after completion

NCP Remedy Selection Criteria	Example Criterion Components	Monitored Natural Recovery	In-Situ Capping	Dredging/Excavation
State Acceptance and Community Acceptance (cont.)		Commonly identified concerns include objections to a "do nothing" remedy, leaving contamination in place, possible spread of contaminants during flooding or other disruption; uncertainties of predicting rates of natural burial; and a potentially lengthy period of fish consumption advisories	Commonly identified concerns include leaving contamination in place, temporary disruption to local residents and businesses, increased truck, rail or barge traffic during capping; temporarily reduced recreational access; potentially long-term reduction of navigational waterway access; reduced access to buried utilities, possible long-term anchoring or other waterway use restrictions, and costs to potentially responsible parties (PRPs) and/or state during O&M	Commonly identified concerns include temporary disruption to local residents and businesses, contaminant releases during dredging, temporary reduction of recreational and navigational waterway access during dredging; siting of and risks from local disposal facilities; and increased truck, rail, or barge traffic during dredging

7.4 COMPARING NET RISK REDUCTION

Each approach to managing contaminated sediment has its own uncertainties and potential relative risks. The concept of comparative net risk reduction was discussed by the NRC as a method to ensure that all positive and negative aspects of each sediment management approach were appropriately considered at contaminated sediment sites. The Committee on Remediation of PCB-Contaminated Sediments states that (NRC 2001):

> All remediation technologies have advantages and disadvantages when applied at a particular site, and it is critical to the risk management that these be identified individually and as completely as possible for each site. For example, managing risks from contaminated sediment in the aqueous environment might result in the creation of additional risks in both aquatic and terrestrial environments... Removal of contaminated materials can adversely impact existing ecosystems and can remobilize contaminants, resulting in additional risks to humans and the environment. Thus, management decisions at a contaminated sediment site should be based on the relative risks of each alternative management action... For a site, it is important to consider "overall" or "net" risk in addition to specific risks.

Project managers are encouraged to use the concept of comparing net risk reduction between alternatives as part of their decision-making process for contaminated sediment sites, within the overall framework of the NCP remedy selection criteria. Consideration should be given not only to risk reduction associated with reduced human and ecological exposure to contaminants, but also to risks introduced by implementing the alternatives. The magnitude of implementation risks associated with each alternative generally is extremely site-specific, as is the time frame over which these risks may apply to the site. Evaluation of both implementation risk and residual risk are existing important parts of the NCP remedy selection process. By evaluating these two concepts in tandem, additional information may be gained to help in the remedy selection process. Highlight 7-4 provides examples of elements that could be evaluated by project managers in this comparative evaluation.

Highlight 7-4: Sample Elements for Comparative Evaluation of Net Risk Reduction

Elements Potentially Reducing Risk

- Reduced exposure to bioavailable/bioaccessible contaminants
- Removal of bioavailable/bioaccessible contaminants
- Removal or containment of buried contaminants that are likely to become bioaccessible

Elements Potentially Continuing or Increasing Risk

For MNR:

- Continued exposure to contaminants already at sediment surface and in food chain
- Potential for undesirable changes in the site's natural processes (e.g., lower sedimentation rate)
- Potential for contaminant exposure due to erosion or human disturbance

For In-Situ Capping:

- Contaminant releases during capping
- Continued exposure to contaminants currently in the food chain
- Other community impacts (e.g., accidents, noise, residential or commercial disruption)
- Worker risk during transport of cap materials and cap placement
- Releases from contaminants remaining outside of capped area
- Potential contaminant movement through cap
- Disruption of benthic community

For Dredging or Excavation:

- Contaminant releases during sediment removal, transport, or disposal
- Continued exposure to contaminants currently in the food chain
- Other community impacts (e.g., accidents, noise, residential or commercial disruption)
- Worker risk during sediment removal and handling
- Residual contamination following sediment removal
- Releases from contaminants remaining outside dredged/excavated area
- Disruption of benthic community

7.5 CONSIDERING INSTITUTIONAL CONTROLS (ICs)

Institutional controls (ICs) such as fish consumption advisories, fishing bans, or ship draft/anchoring/wake controls are common parts of sediment remedies (see Chapter 3, Section 3.6, Institutional Controls). Structural maintenance agreements are another legal mechanism that may be important for protecting some remedies. 40 CFR §300.430(a)(1)(iii)(D) contains the following general EPA expectations with respect to ICs. These expectations generally apply to all Superfund sites, including sediment sites:

- EPA expects to use institutional controls such as water use and deed restrictions to supplement engineering controls as appropriate for short- and long-term management to prevent or limit exposure to hazardous substances, pollutants, or contaminants;

- Institutional controls may be used during the conduct of the RI/FS and implementation of the remedial action and, where necessary, as a component of the completed remedy; and

- The use of institutional controls shall not be substituted for active response measures (e.g., treatment and/or containment of source material, restoration of ground waters to their beneficial uses) as the sole remedy unless such active measures are determined not to be practicable, based on the balancing of trade-offs among alternatives that is conducted during the selection of remedy.

EPA policies concerning ICs are explained in *Institutional Controls: A Site Manager's Guide to Identifying, Evaluating, and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups* (U.S. EPA 2000f). In addition to considering the NCP expectations concerning ICs, the project manager should determine what entities possess the legal authority, capability and willingness to implement, and where applicable, monitor, enforce, and report on the status of the IC. An evaluation should also be made of the durability and effectiveness of any proposed IC. The objectives of any ICs contained in the selected alternative should be clearly stated in the ROD or other decision document together with any relevant performance standards. While the specific IC mechanism need not be identified, the types of ICs envisioned should be discussed in sufficient detail to support a conclusion that effective implementation of the ICs can be reasonably expected. For some federal facilities in the CERCLA program, the IC implementation details (i.e., the specific IC mechanism) should be placed in the ROD. The program manager should refer to EPA's *Guidance on the Resolution of the Post-ROD Dispute* (U.S. EPA 2003d) for guidelines describing and documenting ICs in Federal Facility RODs, Remedial Designs, Remedial Action Workplans, and Federal Facility Agreements/Interagency Agreements.

Reliability and effectiveness of ICs are of particular concern with sediment alternatives, whether they are used alone or in combination with MNR, in-situ capping, or sediment removal. Project managers should recognize that, generally, ICs cannot protect ecological receptors or prevent disruption of an in-situ cap by bottom-dwelling organisms. In addition, in many cases ICs have been only partially effective in modifying human behavior, especially in the case of voluntary or advisory controls. Although fish consumption advisories can be an important component of a sediment remedy, it should be recognized that they are unlikely to be entirely effective in eliminating exposures. Where advisories or bans are relied upon to reduce human health risk for long periods, public education, and where applicable, enforcement by the appropriate agency, are critical. This point is emphasized in EPA's risk management Principle 9, Maximize the Effectiveness of Institutional Controls and Recognize Their Limitations (U.S. EPA 2002a; see Appendix A).

Implementing and overseeing ICs can often be more difficult at sediment sites where control of the water body may involve multiple entities and a single landowner is not present to provide oversight and enforcement. As for other types of sites, at sediment sites, project managers should review ICs during the five-year review. Where a water body is owned or controlled by local, state, or federal government entities, their regulations and guidance should be consulted to determine what governmental controls can be used to restrict the use of the water body, and the regulatory or administrative process to enforce such a restriction. In complex situations, it may be useful to layer a number of different ICs as discussed in the ICs site manager's guide (U.S. EPA 2000f). Additional guidance on other aspects of ICs is under development by EPA.

7.6 CONSIDERING NO-ACTION

As presented in Section 8.1 of the ROD Guidance, a no-action decision may be appropriate in the following situations:

- When the site or operable unit poses no current or potential threat to human health or the environment;
- When CERCLA does not provide the authority to take remedial action; or
- When a previous response(s) has eliminated the need for further remedial response [often called a "no-further-action" alternative].

Generally, if ICs are necessary to control risks caused by a contaminant of concern at a site, a no-action decision is not appropriate. For example, if fish consumption advisories or fishing bans are necessary to control risks from contaminants of concern at a site, a no-action decision for sediment is not appropriate, even if the advisories or bans are already in place. Instead, a remedy should be considered that includes at least the institutional control (e.g., advisories or bans), and, if appropriate, other actions for sediment or other media.

A no-action decision; however, may include monitoring. For example, sediment may pose no unacceptable risk to human health or the environment; however, uncertainties concerning that evaluation may make it wise to continue some level of monitoring. In this case, a no-action decision that includes monitoring may be appropriate. It is important to note that this is different from a MNR remedy where current or expected future risk is unacceptable and natural processes are being relied upon to reduce that risk to an acceptable level within a reasonable time frame. Although a no-action decision may require long-term monitoring, a MNR remedy generally needs more intensive monitoring to show that contaminant concentrations are being reduced by anticipated mechanisms at the predicted rates.

7.7 CONCLUSIONS

The focus of remedy selection should be on selecting the alternative best representing the overall risk reduction strategy for the site according to the NCP nine remedy selection criteria. As discussed in the OSWER Directive 9285.6-08, *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (U.S. EPA 2002a), EPA's policy has been and continues to be that there is no presumptive remedy for any contaminated sediment site, regardless of the contaminant or level of risk. Generally, as discussed in Chapter 3, Feasibility Study Considerations, project managers should evaluate each of the three potential remedy approaches (i.e., MNR, in-situ capping, and removal through dredging or excavation) at every sediment site. Project managers should develop a conceptual site model that considers key site uncertainties. Such a model can be used within an adaptive management approach to control sources and to implement a cost-effective remedy that will achieve long-term protection while minimizing short-term impacts (refer to Chapter 2, Section 2.2 on conceptual site models).

Controlling any continuing sources of contaminants is an important factor for any sediment remedy (U.S. EPA 2002a). Where source control is uncertain, cannot be achieved, or is outside the scope of the remedial action, project managers should consider the potential for recontamination and factor that potential into the remedy selection process and into the long-term monitoring plan for the site. However, project managers should note that delaying an action to complete source control may not always be wise. Early actions in some areas may be appropriate as part of a phased approach to address site-wide contamination even if sources are not fully controlled initially; in such situations, careful consideration should be given as to whether the uncontrolled sources will cause the early action to be ineffective.

At many sites, but especially at large sites, the project manager should consider a combination of sediment approaches as the most effective way to manage the risk. This is because the characteristics of the contaminated sediment and the settings in which it exists are not usually homogeneous throughout a water body (NRC 2001). As discussed in the remedy-specific chapters of this document, when evaluating alternatives, project managers should include realistic assumptions concerning residuals and contaminant releases from in-situ and ex-situ remedies, the potential effects of those residuals and releases, and the length of time a risk may persist.

The project manager should include a scientific analysis of sediment stability in the remedy selection process for all sites where sediment erosion or contaminant transport is a potential concern. Typically, it is not sufficient to assume that a site as a whole is depositional or erosional. Generally, as discussed in Chapter 2, Remedial Investigation Considerations, project managers should make use of available empirical and modeling methods for evaluating sediment stability and fate and transport, especially when there are significant differences between alternatives.

The project manager should include in the remedy selection process a clear analysis of the uncertainties involved, including uncertainties concerning the predicted effectiveness of various alternatives and the time frames for achieving cleanup levels and remedial action objectives. Project managers should quantify, as far as possible, the uncertainty of the factors that are most important to the remedy decision. Where it is not possible to quantify uncertainty, the project manager should use a sensitivity analysis to determine which apparent differences between alternatives are most likely to be significant.

The project manager should monitor all sediment remedies during and after implementation to determine if the actions are effective and if all cleanup levels and remedial action objectives are met. Sediment remedies should not only include monitoring of surficial sediment immediately following implementation of the action, but also long-term monitoring of sediment to assess changes in residual contamination and possible recontamination, as well as monitoring of fish or other relevant biota recovery data. Without these data, an assessment of the long-term effectiveness of the remedy is difficult, and five-year reviews may be difficult to perform accurately. Additional monitoring data may help not only to assess the site but to help build a body of knowledge that will decrease uncertainties in decision making at future sites. Chapter 8, Remedial Action and Long-Term Monitoring, discusses these and other general monitoring considerations for contaminated sediment sites.

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